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(54) **CORE NETWORK OPTIMIZATION OF TOPOLOGY AND TECHNOLOGY FOR TRAFFIC HANDLING**

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(58) **Field of Search** 370/232, 229, 370/230, 252, 351, 389, 465, 466, 469, 400, 401, 403, 335, 356, 392, 402, 449, 395.2, 395.31, 395.32, 395.5, 405, 406, 408; 709/220

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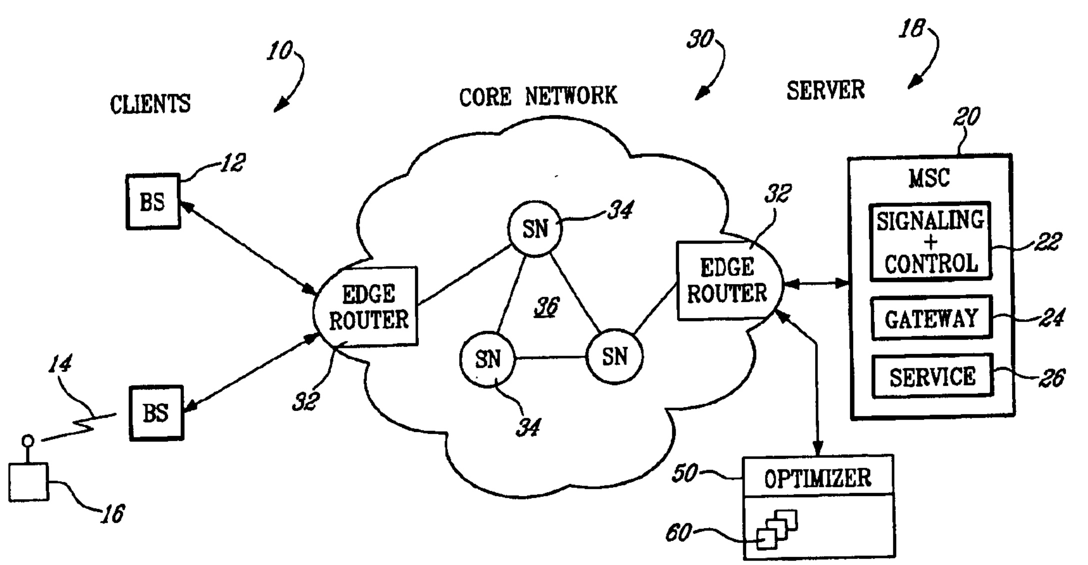
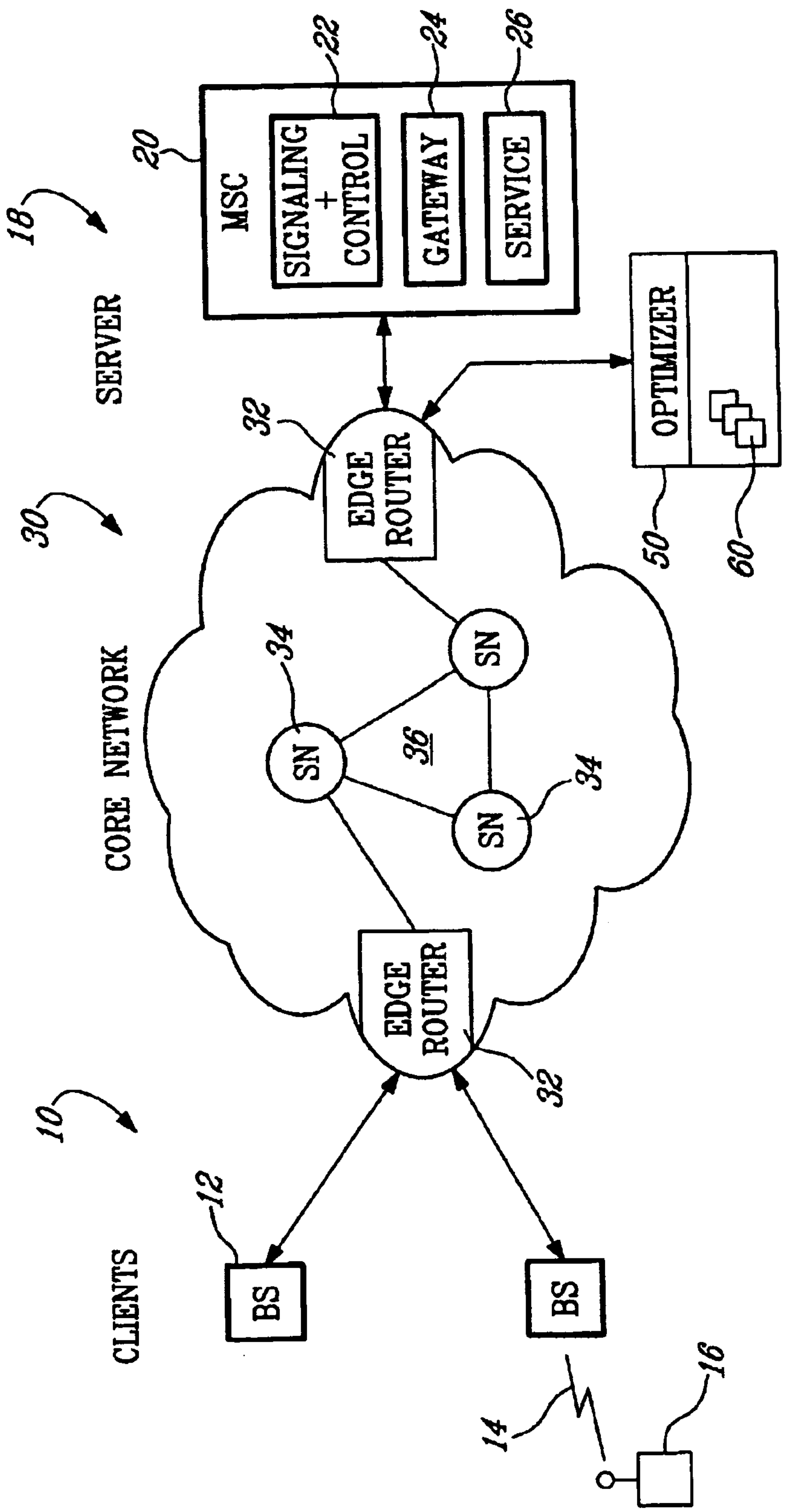
(57) **ABSTRACT**

Routing nodes that are interconnected within a communications network are not configured to utilize a single type of switching technology in the context of a single type of networking topology. Responsive to data input and the operation of an expert system, the routing nodes are configured to implement a certain switching technology type and networking technology type, and thus optimize portions of the communications network to handle different types of traffic. Traffic of the various different types may then be efficiently handled through the network by its correspondingly optimized portion.

17 Claims, 4 Drawing Sheets

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SERVER
20
MSC
22
SIGNALING + CONTROL
24
GATEWAY
26
SERVICE
OPTIMIZER
50
60
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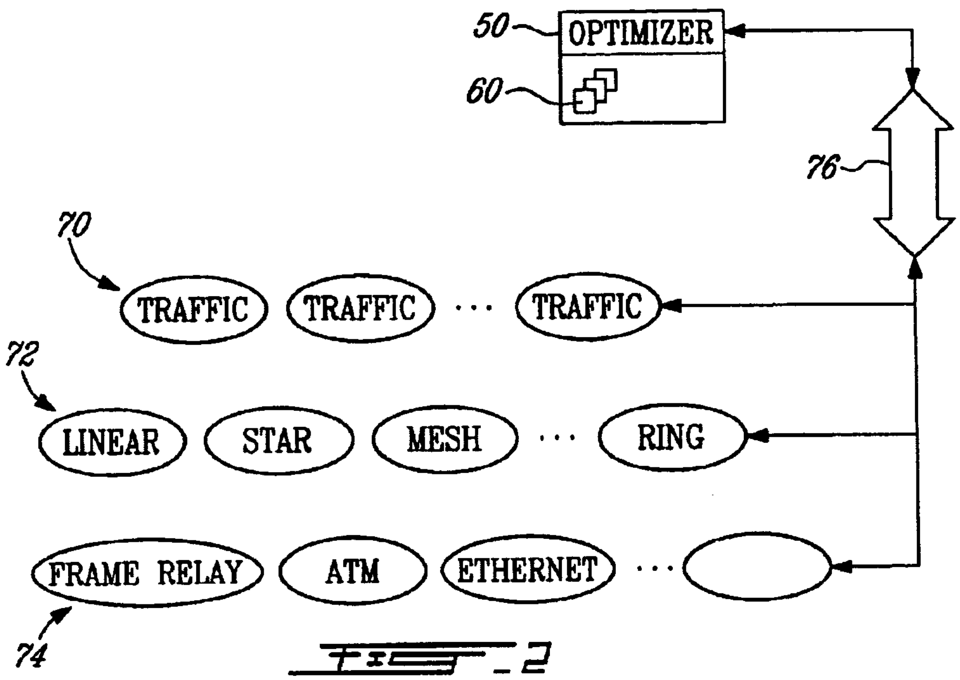
CORE NETWORK
32
EDGE ROUTER
34
SN
36
SN
34
SN
EDGE ROUTER
32
10
CLIENTS
12
BS
BS
14
16

FIG. 1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OPTIMIZER
60
76
70
TRAFFIC
TRAFFIC
TRAFFIC
72
LINEAR
STAR
MESH
RING
FRAME RELAY
ATM
ETHERNET
74

FIG. 2

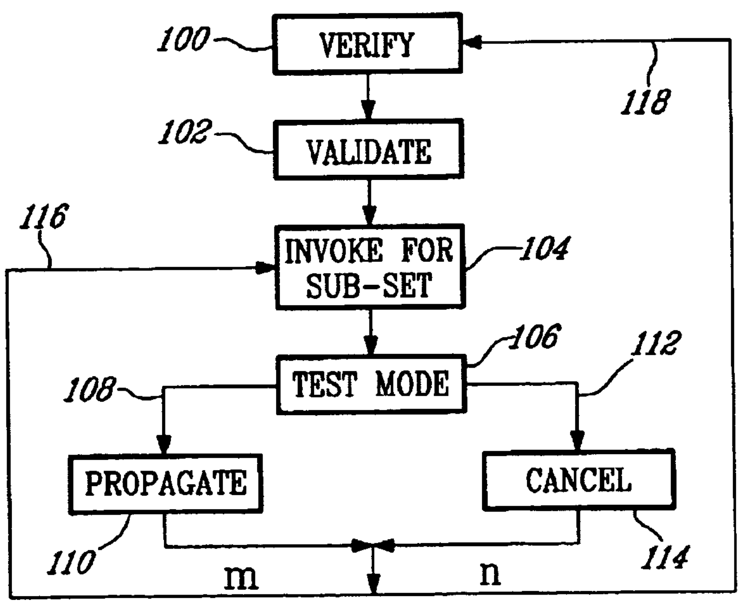
100
VERIFY
118
102
VALIDATE
116
INVOKE FOR SUB-SET
104
106
TEST MODE
112
108
PROPAGATE
CANCEL
110
114
m
n

FIG. 3

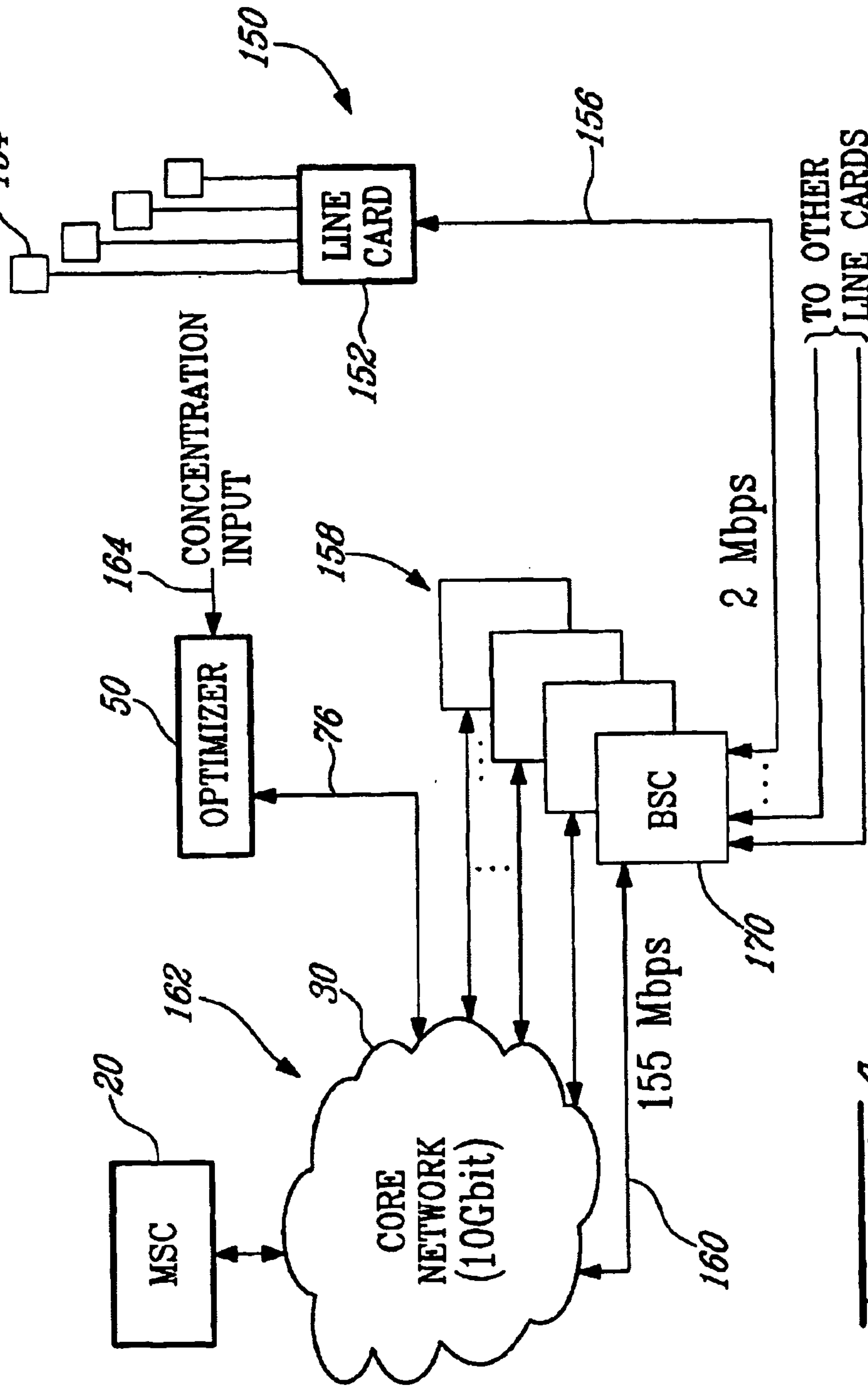
150
154
LINE CARD
156
152
CONCENTRATION INPUT
164
50
OPTIMIZER
76
158
2 Mbps
TO OTHER LINE CARDS
BSC
170
162
30
155 Mbps
20
MSC
CORE NETWORK (10Gbit)
160

FIG. 4

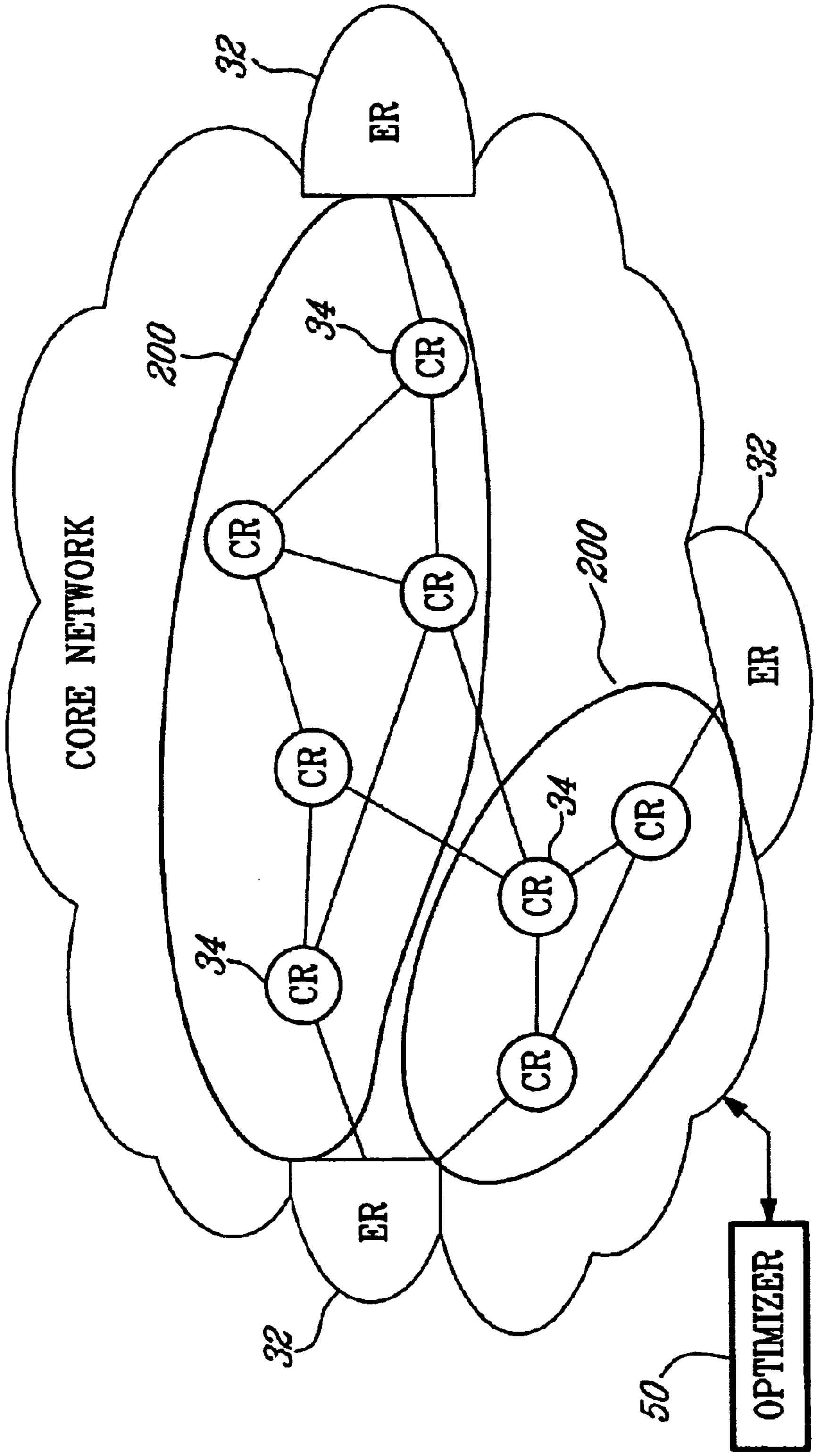
32
ER
200
34
CR
CR
CR
CORE NETWORK
CR
CR
34
CR
200
32
ER
34
CR
CR
CR
ER
32
OPTIMIZER
50

FIG-5

CORE NETWORK OPTIMIZATION OF TOPOLOGY AND TECHNOLOGY FOR TRAFFIC HANDLING

BACKGROUND OF THE INVENTION

1. Technical Field of the Invention

The present invention relates to the management of communications networks and, in particular, to the optimization of topology and technology types within a network to support certain traffic types.

2. Description of Related Art

Historically, communications networks have been designed as tightly coupled systems wherein one traffic type, one technology type, and one topology type are linked together to define and provide communications service through the network. For example, a communications network being designed to primarily handle voice traffic may utilize a completely different selection of technology and topology type than a network being designed to primarily handle data (computer) traffic. It is not unusual, however, for one of these tightly coupled designed networks to handle a wide variety of traffic types, or alternatively for the type of traffic being handled by that network to vary over time. That being the case, instances may arise where the communications network is not configured from a technology and topology perspective to provide optimal service in view of the currently being handled traffic. There is need for greater flexibility in communications network configuration and operation to serve a variety of traffic needs in an optimal fashion.

SUMMARY OF THE INVENTION

Generic routing nodes are interconnected to form a core communications network. By "generic" it is meant that the routing nodes are not configured to utilize a single type of switching technology in the context of a single type of networking topology. Instead, the generic routing nodes are dynamically configured by an optimizer functionality to implement a certain switching technology type and networking topology type, and thus optimize portions of the communications network to handle different types of traffic. Traffic of the various different types may then be routed for handling by its correspondingly optimized portion of the network.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the method and apparatus of the present invention may be acquired by reference to the following Detailed Description when taken in conjunction with the accompanying Drawings wherein:

FIG. 1 is a block diagram of a client/server environment wireless communications network in accordance with the present invention;

FIG. 2 is a logical view of the overall traffic, topology and technology managed by the optimizer functionality;

FIG. 3 is a flow diagram for the process implemented by the optimizer functionality in connection with managing traffic types, topology types and technology types;

FIG. 4 is a block diagram illustrating a layered-type concentration within the network of FIG. 1; and

FIG. 5 is a block diagram illustrating operation of the optimizer to partition the network of FIG. 1 into a plurality of optimized sub-networks.

DETAILED DESCRIPTION OF THE DRAWINGS

Reference is now made to FIG. 1 wherein there is shown a block diagram of a client/server environment wireless communications network in accordance with the present invention. In providing wireless communications services, the clients **10** comprise a plurality of base stations **12** that support subscriber communications over an air interface **14** with a plurality of mobile stations **16**. The server **18** comprises a mobile switching center **20** having functionalities for network signaling and control **22**, gateway operations **24** for interfacing the network to the Internet or an intranet, and service provision **26** for supporting subscriber access to services such as, for example, voice mail, intelligent networking (IN), and the like. Interconnecting the clients **10** to the server **18** is a core network **30** comprised of a plurality of edge routers **32** supporting connections to the base stations **12** and the mobile switching center **20**, and a plurality of cell switch routers **34** that are interconnected **36** in at least an almost fully-meshed network configuration that supports the use of a number of different types of networking topologies (such as, for example, linear, star, mesh, ring, tree, and the like). Some of the cell switch routers **34** support connections to the edge routers **32**.

The edge routers **32** and cell switch routers **34** of the core network **30** comprise generic nodes. By "generic" it is meant that the edge routers **32** and cell switch routers **34** are not configured to utilize a single type of switching technology (such as, for example, frame relay, asynchronous transfer mode (ATM), ethernet, or the like) in the context of a single type of networking topology. Put another way, "generic" refers to an ability of the edge routers **32** and cell switch routers **34** to utilize, on an as needed and specified basis, any one of a number of available switching technologies (such as, for example, those mentioned above) when supporting the routing of subscriber communications through the core network **30** using one of a number of networking topologies (such as, for example, those mentioned above) between the clients **10** and the server **18**. The subscriber communications may be of any traffic type (such as, for example, voice, data, facsimile, video conferencing, and the like).

The network includes an optimizer functionality **50** that implements a layered-type concentration mechanism to ensure proper distribution of the required subscriber traffic to the right place, at the right time, and with the appropriate bandwidth granularity. A layered-type concentration mechanism categorizes the available switching mechanisms (such as, for example, the edge routers, cell switch routers, base station switching capabilities, line card switching capabilities, and the like) based on their aggregate size and level of concentration represented (for instance, 10 Gbit WAN concentration, 155 Mbps concentration, and 2 Mbps concentration). To reach this goal, the optimizer functionality **50** utilizes an optimized virtual traffic, topology and technology concept that manages the topology and technology used within the core network **30** (by controlling generic cell switch router and edge router configuration) and confines subscriber traffic to that portion of the core network that has been optimized (based on a topology and technology selection implemented through the generic cell switch routers and edge routers) to handle a specific type of subscriber traffic.

Object oriented design templates **60**, referred to herein as "optimizer constituents classes", specify certain associations of traffic type, topology type and technology type that most efficiently support certain communication(s) through the core network **30** (i.e., optimize the core network for that

communication). These templates **60**, which may be instantiated as objects with their associated methods (i.e., operations) to be invoked, are maintained in the optimizer functionality **50** and are downloaded for storage in local memory (not shown) within the edge routers **32** and generic cell switch routers **34**. Responsive to communications support needs within the core network **30**, the optimizer functionality **50** then invokes the operations associated with selected ones of the templates **60** at each implicated edge router **32** and/or generic switch node **34** to configure the core network **30**, through the individual router nodes, to implement a desired network optimization.

Reference is now made to FIG. **2** wherein there is shown a logical view of the overall traffic **70**, topology **72** and technology **74** managed by the optimizer functionality **50**. The double arrow **76** represents the two-way activity produced by processes that are spawned and the operations that are invoked across the different implicated edge routers **32** and/or cell switch routers **34** to represent and control traffic **70** types, topology **72** types and technology **74** types during core network configuration. This two-way activity **76**, generally speaking, results in data collection concerning the present network configuration, procurement to switching nodes of the optimizer constituents, utilization of an expert system to select and invoke needed configuration methods, and testing of network operation to confirm optimization.

Reference is now made to FIG. **3** wherein there is shown a flow diagram for the two-way activity **76** implemented by the optimizer functionality **50** in connection with managing traffic **70** types, topology **72** types and technology **74** types. In step **100**, the optimizer functionality **50** verifies the edge routers **32** and cell switch routers **34** currently present within the core network **30**. This verification may be performed, for example, through a polling exercise where identification requests are made of the switching node, and acknowledgments are monitored from the active nodes. In step **102**, the optimizer functionality **50** validates the identity of the active (i.e., acknowledging) nodes. A copy of the currently in effect templates **60** representing the optimizer constituent classes are then downloaded as objects from the optimizer functionality **50** to the validated, active nodes.

Next, in step **104**, the optimizer functionality **50** invokes the operations associated with selected ones of the traffic **70** types, topology **72** types and technology **74** types at certain ones of the edge routers **32** and/or generic cell switch routers **34** to configure a sub-set of resources (such as, for example, virtual circuits, routers, connection admission control, and the like) within the core network **30**, through the individual implicated router nodes of that sub-set of resources, to implement a desired network optimization. The action of step **104** is taken only when needed to effectuate an updating to the optimization of the network. This determination is made by an expert system of the optimizer functionality **50** in response to a monitoring of network operation or a change in traffic type and/or volume of certain types of traffic being handled by the core network **30** and/or network condition (in terms of link failure, node addition or deletion, and the like). Following each instance of a newly implemented network optimization, the process, in step **106**, enters a test mode utilizing a dedicated test virtual channel to determine whether the newly implemented optimizer constituents meet or exceed an expected level of network optimization. This test mode procedure is preferably implemented within only that sub-set of the overall network that has been reconfigured. If yes (branch **108**), the operations for the selected ones of the optimizer constituents are propagated in step **110** throughout an affected portion (i.e., a number of resources such as, for example, virtual circuits, larger than the originally affected sub-set of resources) of the core network **30**. If no (branch **112**), the optimizer constituents previously implemented within the sub-set of the network are canceled in step **114**. In one implementation, the process then loops **116** back to step **104** after "m" time periods or loops **118** back to step **100** after "n" time periods, wherein n>m, to effectuate periodic dynamic optimization of the network configuration. In an alternative implementation, the process loops **116** back to step **104** when triggered by a first event (for example, comprising a certain network status or state or data change), or loops **118** back to step **100** when triggered by a second event (for example, comprising a certain network status or state or data change), to effectuate sporadic dynamic optimization of the network configuration.

Reference is now made to FIG. **4** wherein there is shown a block diagram illustrating a layered-type concentration within the network of FIG. **1**. In this example, three levels of concentration are provided. The first level **150** is located at the line card **152** which concentrates calls from a plurality of cells **154** (for example, comprising time slots on a given air interface **14** frequency) onto a single 2 Mbps link **156**. The second level **158** is located at the base station controller (i.e., the remote switching point) **170** which concentrates a plurality of links **156** together onto a single 155 Mbps link **160**. The third level **162** is located at the core network **30** and mobile switching center **20** which concentrates a plurality of links **160** together to provide 10 Gbit service.

The system accordingly implements a layered control part that is divided into the previously recited three levels of concentration. Responsive to input data **164** concerning these levels of concentration (e.g., link failure, node addition or deletion, and the like) and the type of traffic being handled at the various levels of concentration, the optimizer **50** (through its expert system) provides triggers for the selection of traffic **70** types, topology **72** types and technology **74** types. What this accomplishes is that certain types of traffic are confined by the actions of the optimizer **50** to a portion of the core network **30** that has been optimized, through the selection of topology and technology, to handle that traffic. Of course, it is understood, that other portions of the core network **30** have been similarly optimized based on topology and technology selection and configuration to handle other types of traffic. The function of the edge routers and cell switch routers within the core network then is to properly route the traffic to its corresponding technology and topology optimized portion.

The expert system implemented by the optimizer functionality **50** relies on artificial intelligence in order to emulate the kind of intelligent behavior shown by experts. Expert systems contain a knowledge base and an inference engine. The knowledge base contains the specific domain knowledge (or facts), and the inference engine controls the reasoning process and user interface. In the context of the two-way activity **76** illustrated by FIG. **3**, the expert system implements the actions of step **104** wherein the methods associated with the traffic **70** types, topology **72** types and technology **74** types are selected and then invoked at certain ones of the edge routers **32** and/or generic cell switch routers **34** to configure a sub-set of resources within the core network **30**, through the individual implicated switching nodes, to implement a desired network optimization.

Configuration of an expert system to make optimization decisions is well within the capabilities of one skilled in the arts of artificial intelligence and expert system design. A more complete understanding of expert system operation and optimization decision-making may be obtained by reference to the following examples.

In a first example, the knowledge base may comprise information that the network under consideration for optimization must withstand worst-case traffic with a long-term dependency (i.e., self-similar traffic), and that the network is packet switched. Operation of the inference engine in the context of this knowledge base may produce the following optimization of the network: 1)voice traffic is given first priority, video conferencing traffic is given second priority, and Internet traffic is given lowest priority and is shaped with a 50 msec delay in order not to degrade other user flows; 2) the topology type is partially meshed for datagram routing; and, 3) the technology type is IP packets over ATM for quality of service.

In a second example, the knowledge base may comprise information that the network under consideration for optimization is a legacy circuit-switched application that must provide for hard end-to-end guaranteed performance. Operation of the inference engine in the context of this knowledge base may produce the following optimization of the network: 1) with legacy traffic, all types are of equal priority with hard end-to-end performances; 2) the topology type is a star for limited routing end-points; and, 3) the technology is ATM for circuit emulation over AAL1.

In a third example, the knowledge base may comprise information that the network under consideration for optimization is to be divided into sub-networks, and the sub-network under consideration for optimization is to handle 80% packet switched and 20% circuit switched emulated traffic. Operation of the inference engine in the context of this knowledge base may produce the following optimization of the network: 1) the packet switched traffic is scheduled with a prioritization scheme buffer and that the circuit switched emulated traffic cannot accept a cell delay variation greater than a certain threshold; 2) the topology type is a combination of mesh and tree; and, 3) the technology type is IP over multiple protocol label switching (MPLS) for packet switched traffic and ATM native emulation service for the circuit switched emulated traffic, with both technologies implementing a ship-in-the-night mode of operation.

In a fourth example, the knowledge base may comprise information that the network under consideration for optimization is a simple office, home office (SOHO) environment where 384 Kbps flows are required in a certain number of houses per point of presence. Operation of the inference engine in the context of this knowledge base may produce the following optimization of the network: 1) the SOHO traffic requires connections to H.323 codecs and signaling; 2) the topology type is a tree from the point of presence (i.e., a point to multi-point arrangement); and, 3) the technology type is MPLS with extended LDP for support of "set-up to N" and "tear-down from M" messages in order to negotiate add-on and deletion of leaves.

In each of the foregoing examples, once the selections are made by the expert system of the optimizer **50**, the methods associated with the selected traffic **70** types, topology **72** types and technology **74** types are invoked at certain ones of the edge routers **32** and/or generic cell switch routers **34** to configure a sub-set of resources within the core network **30**, through the individual implicated switching nodes, to implement a desired network optimization. Thus, it is seen that given certain concentration input **164** and other data relating to the knowledge base, the inference engine is capable of selecting both technology and topology for the network as well as priorities for traffic handling in order to provide an optimized configuration. Put another way, the expert system evaluates known facts and applies certain rules to configure the overall network (in terms of technology and topology) in a way that differs from a preset default configuration. By keeping track of the known facts, and applying the rules on either a periodic or sporadic basis, dynamic modification of the network configuration may be implemented to maintain the network in an optimal configuration for handling communications.

Reference is now made to FIG. **5** wherein there is shown a block diagram illustrating operation of the optimizer to partition the network of FIG. **1** into a plurality of optimized sub-networks. In some instances, the concentration input **164** and other data relating to the knowledge base that are processed by the expert system dictate an inference that the network must be partitioned into plural sub-networks **200**, with each sub-network optimized in accordance with the operation of the expert system to provide certain communications service. The plural sub-networks **200** interact with each other as needed, and may (if necessary) have overlapping or shared resources (including, for example, virtual circuits and nodes). Within each sub-network, however, the included nodes are configured by invoking the methods associated with the selected traffic **70** types, topology **72** types and technology **74** types to provide optimal performance tailored to the needs of the traffic being handled. Thus, the network further functions, responsive to the presence of plural optimized sub-networks **200**, to route and confine traffic to the appropriate correspondingly optimized sub-network. The third example discussed above illustrates how two sub-networks **200**, one for packet switched traffic and another for circuit switched emulated traffic may be configured by the optimizer **50**.

Although preferred embodiments of the method and apparatus of the present invention have been illustrated in the accompanying Drawings and described in the foregoing Detailed Description, it will be understood that the invention is not limited to the embodiments disclosed, but is capable of numerous rearrangements, modifications and substitutions without departing from the spirit of the invention as set forth and defined by the following claims.

What is claimed is:

1. A core communications network, comprising:

a plurality of cell switched routers interconnected in at least a partially meshed configuration;

a plurality of edge routers connected to certain ones of the plurality of cell switched routers and supporting edge connection outside the core communications network;

wherein the cell switched routers and edge routers support utilization of any selected one of a plurality of switching technologies in the context of any selected one of a plurality of networking topologies; and

a functionality for dynamically selecting a switching technology for utilization by each cell switched router and edge router and for selecting a networking topology for connecting the plurality of cell switched routers and edge routers in order to optimize operation of the core communications network.

2. The communications network as in claim **1**:

wherein the plurality of switching technologies supported at each cell switched router and edge router include at least two of the following: frame relay, asynchronous transfer mode, and ethernet; and

wherein the plurality of networking topologies supported for connecting the cell switched routers and edge routers include at least two of the following: linear, star, mesh, ring and tree.

3. The communications network as in claim **1** wherein the functionality comprises an expert system to select switching technology and networking topology.

4. The communications network as in claim **1**:

wherein each cell switched router and edge router stores a plurality of object oriented design templates concerning traffic, technology and topology; and

wherein the functionality invokes operations associated with selected templates in selecting a switching technology for utilization by each cell switched router and edge router and selecting a networking topology for connecting the plurality of cell switched routers and edge routers in order to implement a desired optimization of the communications network.

5. A cellular communications system, comprising:

a mobile switching center;

a plurality of base stations, each supporting air interface communications with mobile stations; and

a core communications network for interconnecting the mobile switching center to the plurality of base stations, the core communications network comprising:

a plurality of cell switched routers interconnected in at least a partially meshed configuration;

a plurality of edge routers connected to certain ones of the plurality of cell switched routers and supporting edge connection to the plurality of base stations and the mobile switching center;

wherein the cell switched routers and edge routers support utilization of any selected one of a plurality of switching technologies in the context of any selected one of a plurality of networking topologies; and

a functionality for dynamically selecting a switching technology for utilization by each cell switched router and edge router and for selecting a networking topology for connecting the plurality of cell switched routers and edge routers in order to optimize operation of the core communications network.

6. The cellular communications system as in claim 5:

wherein the plurality of switching technologies supported at each cell switched router and edge router include at least two of the following: frame relay, asynchronous transfer mode, and ethernet; and

wherein the plurality of networking topologies supported for connecting the cell switched routers and edge routers include at least two of the following: linear, star, mesh, ring and tree.

7. The cellular communications system as in claim 5 wherein the functionality comprises an expert system to select switching technology and networking topology.

8. The cellular communications system as in claim 5:

wherein each cell switched router and edge router stores a plurality of object oriented design templates concerning traffic, technology and topology; and

wherein the functionality invokes operations associated with selected templates in selecting a switching technology for utilization by each cell switched router and edge router and selecting a networking topology for connecting the plurality of cell switched routers and edge routers in order to implement a desired optimization of the communications network.

9. A method for optimizing a core communications network including a plurality of cell switched routers interconnected in at least a partially meshed configuration, and a plurality of edge routers connected to certain ones of the plurality of cell switched routers and supporting edge connection outside the core communications network, wherein the cell switched routers and edge routers support utilization of any selected one of a plurality of switching technologies in the context of any selected one of a plurality of networking topologies, the method comprising the steps of:

verifying the presence of cell switched routers and edge routers within the core communications network;

validating the present cell switched routers and edge routers;

invoking operations within a sub-set of the cell switched routers and edge routers to select an optimal switching technology and networking topology;

placing the sub-set of the cell switched routers and edge routers into a test mode to confirm optimal configuration; and

propagating the operations to other cell switched routers and edge routers outside the sub-set if optimal configuration is confirmed.

10. The method as in claim 9 wherein the recited method is performed periodically to dynamically optimize core communications network configuration.

11. The method as in claim 9 wherein the recited method is performed sporadically to dynamically optimize core communications network configuration.

12. The method as in claim 9 further including the step of:

partitioning the core communications network into a plurality of sub-networks;

wherein the recited method is performed for each sub-network to optimize its sub-network configuration.

13. A method for optimizing a core communications network including a plurality of cell switched routers interconnected in at least a partially meshed configuration, and a plurality of edge routers connected to certain ones of the plurality of cell switched routers and supporting edge connection outside the core communications network, wherein the cell switched routers and edge routers support utilization of any selected one of a plurality of switching technologies in the context of any selected one of a plurality of networking topologies, the method comprising the steps of:

collecting knowledge base information concerning network operation;

inferencing from the collected knowledge base information a preferred switching technology and networking topology that would optimize network configuration; and

implementing the preferred switching technology and networking topology at certain implicated cell switched routers and edge routers to optimize network configuration.

14. The method as in claim 13 further including the step of:

partitioning the core communications network into a plurality of sub-networks;

wherein the recited method is performed for each sub-network to optimize its sub-network configuration, and the certain implicated cell switched routers and edge routers comprise those routers within each respective sub-network.

15. The method as in claim 13 wherein the step of implementing comprises the steps of:

invoking operations within a sub-set of the cell switched routers and edge routers to select the preferred switching technology and networking topology;

placing the sub-set of the cell switched routers and edge routers into a test mode to confirm optimal configuration; and

propagating the operations to other cell switched routers and edge routers outside the sub-set if optimal configuration is confirmed.

16. The method as in claim 13 wherein the recited method is performed periodically to dynamically optimize core communications network configuration.

17. The method as in claim 13 wherein the recited method is performed sporadically to dynamically optimize core communications network configuration.

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